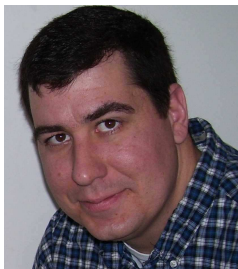


NON-SUSY SEARCHES AT THE TEVATRON

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The CDF and D0 collaborations have results on a large number of searches for beyond-the-standard-model phenomena. This talk focuses on searches for non-supersymmetric model signatures. These results, based on between $1\text{--}2.5\text{ fb}^{-1}$ of data from $p\bar{p}$ collisions at the Fermilab Tevatron, include some of the world's best limits on extra dimensions models and heavy resonances.

1 Extra Dimension Searches

Extra dimensions models have been proposed as a possible solution to the hierarchy problem. In ADD extra dimensions models (proposed by Arkani-Hamed, Dimopoulos, and Dvali), standard model particles are confined to the normal three spacial dimensions, while gravitons can propagate in some number of extra dimensions¹.

In $p\bar{p}$ collisions, it is possible for a graviton to be produced in association with a photon. This graviton can then escape into the extra dimensions, resulting in a detector signature of a single photon and missing transverse energy (MET). The D0 collaboration has results on the search for this mono-photon signature based on 1 fb^{-1} of data². This search requires a single photon in the detector with transverse momentum (p_T) above $90\text{ GeV}/c$ and MET above 70 GeV . The main backgrounds for this search are vector boson production in association with a photon (where the Z boson decays to neutrinos or the charged lepton from the W boson decay is lost), and instrumental backgrounds. Instrumental backgrounds include jets misidentified as photons, W bosons decaying to electrons (when the electron is misidentified as a photon), cosmic rays, and beam halo events. After all selections, a total of 29 events are observed in data, while 22.37 ± 2.50 background events are predicted. 95% confidence level (CL) limits on the fundamental Planck scale (M_D) are computed as a function of the number of extra dimensions. These limits vary from $884\text{ GeV}/c^2$ for two extra dimensions to $779\text{ GeV}/c^2$ for eight extra dimensions.

^aOn behalf of the CDF and D0 collaborations.

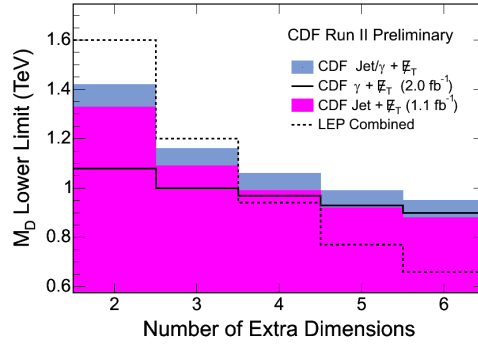


Figure 1: The 95% CL lower limit on the fundamental Planck scale (M_D) versus the number of extra dimensions for the CDF photon plus MET search, jets plus MET search, and the combination.

The CDF collaboration has also performed a search for ADD extra dimensions by looking for events with a single photon and MET³. This search uses 2 fb^{-1} of data and requires a single photon with transverse energy (E_T) above 50 GeV and MET greater than 90 GeV . As in the D0 search, the dominant background is the production of a Z boson in association with a photon, with the Z boson decaying to neutrinos. After all selections, 40 events are observed in data with an expected background of 46.7 ± 3.0 events. 95% CL limits on the fundamental Planck mass (M_D) are calculated that vary from $1080\text{ GeV}/c^2$ for two extra dimensions to $900\text{ GeV}/c^2$ for six extra dimensions.

ADD extra dimensions can also produce a quark in association with a graviton. If the graviton escapes into the extra dimensions, the detector signature will be jets in association with MET. The CDF collaboration has also combined the photon plus MET results with an analysis using jets with MET. The 95% CL limits from the photon plus MET search combined with the jets plus MET search on M_D vary from $1420\text{ GeV}/c^2$ for two extra dimensions to $950\text{ GeV}/c^2$ for six extra dimensions. The limits from the photon plus MET search, the jets plus MET search, and the combination are shown in Fig. 1.

Another model for extra dimensions is that of Randall and Sundrum⁴. In Randall-Sundrum (RS) extra dimensions, standard model particles are confined to a 3-brane and gravity originates on a different 3-brane. Only gravitons can propagate in the bulk between these 3-branes. This model predicts that gravitons will appear as a tower of Kaluza-Klein states.

The D0 collaboration has performed a search for RS gravitons decaying to electrons or photons with 1 fb^{-1} of data⁵. Events are selected that contain two clusters of energy in the electromagnetic calorimeter that have p_T above $25\text{ GeV}/c$. Since no track is required in the central tracking system, this selection is sensitive to both electrons and photons. The primary background is instrumental — jets which are misidentified as electromagnetic objects. Events are counted in a sliding window in the invariant mass distribution of the two electromagnetic objects. The size of this window has been optimized from a simulation of the detector response to RS gravitons with a range of masses. The observed number of events is consistent with the expected background, so 95% CL limits are computed for the mass of the first Kaluza-Klein excitation of the graviton (M_1) as a function of coupling of the graviton to standard model particles (k/\overline{M}_{Pl}). For k/\overline{M}_{Pl} of 0.1, gravitons with a mass below $900\text{ GeV}/c^2$ are excluded. The CDF collaboration has performed a similar search in the dielectron channel with 2.5 fb^{-1} of data that excludes gravitons with a mass below $850\text{ GeV}/c^2$ for the same value of k/\overline{M}_{Pl} ⁶.

RS gravitons can also decay to Z bosons. The CDF collaboration has performed a search for RS gravitons decaying to two Z bosons, which in turn decay to electrons, using 1.1 fb^{-1} of data⁷. Events are selected that contain four electrons. The large number of electrons in

the final state makes the efficiency for identifying electrons critical for this search. Specialized electron reconstructed algorithms were implemented that show a factor of 2–4 improvement over the standard algorithms. The dominant background for this search is hadrons faking electrons. This background was estimated using data events in the low-mass region, which is devoid of the expected signal. There are no events present after all selections in the signal region, with $0.028 \pm 0.009(\text{stat.}) \pm 0.011(\text{syst.})$ expected background events. 95% CL limits on the production cross section times branching ratio of gravitons to Z bosons are computed that vary from 4 – 6 pb for gravitons with a mass between 500 and 1000 GeV/c^2 and k/\overline{M}_{Pl} of 0.1.

2 Resonance Searches

There are a large number of new physics models that predict massive particles that would decay to quarks, leptons, or gauge bosons. Examples of these models include Kaluza-Klein excitations in extra dimensions models (such as the RS gravitons discussed in the previous section), excited quarks or leptons, or new gauge bosons. Since there are many possible models that predict a similar detector signature, these searches are usually designed to be signature-based. That is, pairs of standard model particles are selected (such as dileptons and dijets), and the invariant mass distribution of the pair of standard model objects is examined for deviations from the standard model prediction.

The CDF collaboration has performed a search for a high mass resonance in dijet events with 1.13 fb^{-1} of data⁸. This search selects events with jets with the the absolute value of rapidity less than 1.0 and a dijet mass above 180 GeV/c^2 . At large invariant masses, the spectrum should be smoothly falling. Any “bump” in this spectrum would be an indication of new physics. The invariant mass distribution is fit with a smooth function. The functional form was determined by Pythia and Herwig simulations, but the fit parameters are determined from data. No deviation from the standard model is observed, so limits are set on a variety of models. Excited quarks with masses between 260 and 870 GeV/c^2 are excluded at 95% CL. Limits are also set on the mass of new gauge bosons, referred to as W' and Z' bosons, which are predicted in some new physics models that contain additional gauge fields. W' bosons with masses between 280 and 840 GeV/c^2 and Z' bosons with masses between 320 and 740 GeV/c^2 are excluded.^b

The CDF collaboration has also performed a search for massive resonances that decay to pairs of electrons, using 2.5 fb^{-1} of data⁶. This search requires two electrons with E_T larger than 25 GeV. The search region in the mass distribution is chosen to include invariant masses between 150 and 1000 GeV/c^2 . The dominant, and irreducible, background is standard model Drell-Yan electron production. The shape of this background is taken from detector simulations and the background is normalized to data in the region of the Z boson mass. There are also smaller backgrounds from standard model diboson production and instrumental backgrounds from jets misidentified as electrons. The dielectron mass distribution is shown in Fig. 2. The largest discrepancy in an unbinned maximum likelihood fit for data events with invariant mass above 150 GeV/c^2 is a 3.8σ excess in the range from 228 to 250 GeV/c^2 . Ensemble tests show that the probability of observing a discrepancy of this size anywhere in the mass range from 150 to 1000 GeV/c^2 is 0.6%. No claim of new physics is made, and limits are set on a variety of models. A Z' boson (with standard model couplings) with a mass below 966 GeV/c^2 is excluded at 95% CL. Limits are also set on RS gravitons (which were previously discussed) and new Z bosons in an E_6 model. The limits on RS gravitons and Z' bosons are shown in Fig. 3.

^bThis search assumed that the W' and Z' bosons would have couplings similar to the standard model W and Z boson.

CDF Run II Preliminary

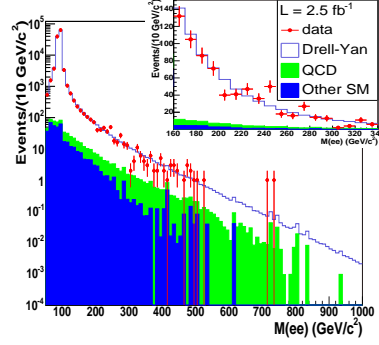
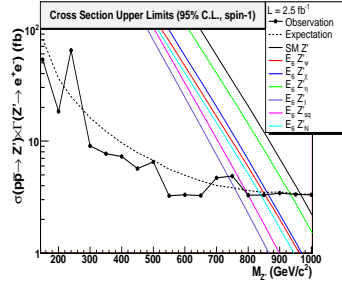


Figure 2: Invariant mass distribution for the CDF dielectron resonance search. The inset shows the region around $240 \text{ GeV}/c^2$ in linear scale.

CDF Run II Preliminary



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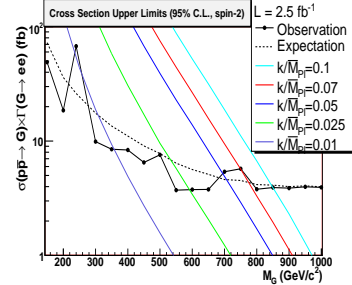


Figure 3: 95% CL limit from the CDF dielectron resonance search for various Z' bosons (left) and RS gravitons (right).

3 Conclusion

The CDF and D0 collaborations have performed a large number of searches for new physics in a wide variety of models. The results presented here use up to 2.5 fb^{-1} of data and represent some of the world's best limits on extra dimensions models and heavy resonances. Although the results presented here concentrated on extra dimensions models and heavy resonances, both experiments have a large number of results on other new physics models. Furthermore, both experiments continue to collect data with high efficiency and so both improvements to existing results and new searches can be expected in the future.

References

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